

PROCESSES AND INSTRUMENTS OF PRACTICAL VALUE IN CARRYING OUT SCIENTIFIC ENQUIRIES BEARING UPON MEDICINE.

THE APHEMETRIC COMPASS; * AN INSTRUMENT FOR MEASURING THE DEGREE OF DISCRIMINATIVE POWER, AS REGARDS CONTACTILE IMPRESSIONS, ENJOYED BY THE SKIN AND MUCOUS MEMBRANES IN CERTAIN AFFECTIONS OF THE NERVOUS SYSTEM.

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IN the year 1834 a pamphlet, consisting of a series of Anatomical and Physiological Annotations "*De pulsû, auditû, resorptionê et tactû*," was published at Leipsic, by Professor Ernest H. Weber. In one of the chapters, that entitled "*De subtilitate tactûs diversâ*," &c., page 44, in addition to other sections upon the perception of heat, and the estimation of the weight of bodies by the sense of touch, is one section, headed "*Experimenta de distantîâ duorum corporum organon tactûs simul tangentium recte perceptâ*," and in this section are several propositions or enunciations, of which three specially and directly bearing on the object of this communication run as follows.

1stly. That various parts of the body are endowed with the faculty, by virtue of the organ of touch, (but not in an equal degree,) of clearly recognising two substances by which they are simultaneously touched. This degree of endowment may be measured by the exact distance existing between those two substances touching the part; for this is peculiar to the organ of touch, that if it does not distinctly recognise two substances touching the skin at but a slight distance from each other, it will, nevertheless, distinctly recognise them, if this distance between them be increased to a certain limit. (Page 47.)

2ndly. That we perceive the distance and position of two substances by which we are simultaneously touched, more distinctly if they be placed transversely to the axis of the body, than when placed in the longitudinal diameter. (Page 49.) †

* From *ἀφή*, i. e. a touching or close contact; or the sense of touch, as used by Plato and Aretæus.

† This does not hold good for every part of the body.

3dly. That in those parts of the body simultaneously touched, in which the points of the compass touching are clearly recognised, although at no great distance from each other, the distance between them appears to be much greater than in parts not endowed with so exquisite a sense of touch, (*i. e.* with such discriminative power).

This last statement is remarkably well illustrated by Weber, at page 148 of his paper. He says that if the points of a compass, at about the distance from each other, of the breadth of the thumb, be brought into contact (simultaneously) with the skin of the cheek near the ear, the distance existing between them will be recognised as very small, or will perhaps not be perceived at all; but, inasmuch as the anterior part of the cheek enjoys a more subtle sense of touch, and still more the lip, especially the middle portion thereof, if the compasses be gently drawn along the skin towards the middle of the lip, its points, although maintained at the same distance, will appear to become gradually separated, in proportion to their proximity to the lip.

Moreover, the points of the compass brought simultaneously into contact with the skin, in a longitudinal direction, appear to be much closer to each other than if they are placed in a horizontal direction, as respects the axis of the body or the limb (page 151); also, points touching the skin on different sides of the median line, appear to be more distant than when they touch it on one or other side alone. Again, such points seem much more distant, and are more clearly perceived when touching *two* contiguous surfaces subjected to voluntary motion, than when they only touch a *single* one; as is shown by the difference of impression produced, by placing both the points of the compass on one lip, and by placing one point on each of the lips (page 60).

In addition to the above observations regarding tactile discrimination, many others of the highest physiological interest might be quoted from Weber's paper; but as my object here is not to render an analysis of the whole of Weber's tract, but merely to point out such salient points therein met with as may be of a more practical and clinical character, and such as more immediately connect themselves with the purposes to which the instrument which I am about to describe, is applicable, I will forbear to quote further in a direct way from the paper in question.*

* One or two points regarding the details requisite for duly and scientifically carrying out the experiments, may here be timely enjoined. For instance, as Weber observes, great stress must be laid on the fact, that the substances brought into contact with the surface of the body, should, as much as possible, be of the

In the pursuit of his observations, Weber at first made use of an instrument termed in Germany a "*Stangenzirkel*," consisting of a long and straight piece of steel to which at right angles are attached two moveable points which may be approximated or separated in a straight line. By means of these moveable points, shielded by cork, he ascertained the exact distances or limits within which two distinct cutaneous impressions, made at the same time, are capable or not of being identified. Subsequently he adopted the steel compass of ordinary mathematical use, blunted at the points; and it was with this last instrument, of which my aphemetric compass is a modification, that his observations upon himself and others as to the contactile sensibility and discrimination of the skin were made.

Most of our physiological works give a summary of the results obtained by Weber's instrument as regards this contactile appreciation, etc.,* and therefore it would here be out of place for me to repeat them.† It may suffice to say that at the tip of the tongue and at the palmar surface of the third phalanx of the fingers‡ separate objects or points brought simultaneously into contact with the surface might be identified, having a shorter distance between them than in any other part of the body; and at the above-mentioned part of the tongue, contactile impressions resulting from two applied points, would be distinctly appreciated if on the average only distant from each other about half of a Paris line (*i.e.*, equal to about $\frac{1}{2}$ th of an inch, according to English measurement).§ Whereas at the middle of the fore-

same form, material, and temperature. It is of course absolutely necessary, that the two points should be brought into connection with the skin exactly at the same moment of time, for otherwise they will appear to be at a greater distance apart than they really are, and also with equal force and pressure. Also, that the eyes of the person experimented on be closed or averted, and that no cause for distraction of the attention be in any way permitted. For a similar reason, and to prevent confusion between distinct kinds of cutaneous impression, the points of the object in contact with the skin must not be so sharp as to inflict pain, or so hot or cold as to give the impression of difference of temperature.

* I have ventured to use the epithet "*contactile discrimination*," substituting it for the expression "*tactile sense*" of Weber, because we now, I think, more clearly understand the analysis of the so-termed general tactile sense, and recognize its division into the four subordinate tactile senses of, 1st, Temperature; 2nd, Pain; 3rd, Muscular action; and 4th, *Contactility*, as shown by Landry and others.

† See article "Touch" by Carpenter, in Todd's *Cyclopædia of Anatomy and Physiology*, p. 1163; also Wagner's "*Handwörterbuch*" article, *Nervenphysiologie*, vol. ii. p. 568; also Baly's "*Translation of Müller's Physiology*," vol. i. p. 751.

‡ In some of our authorities it is erroneously stated that Weber found the phalanx of the third finger to be the most highly endowed with this tactile discriminative power; whereas it is the third phalanx of *all* the fingers of which he speaks.

§ Even at this minute distance apart it was at this place quite possible to recognize whether the two points in contact with the surface were placed at right angles to, or parallel with the axis of the body.

arm, thigh, and back, the applied points of the compass must generally, in a natural condition, be as much as 30 lines apart before they can thoroughly be identified.

Weber gives a very elaborate and lengthy as well as a shorter or condensed enumeration of the various parts of the surface of the body, as observed on his own person, with the qualifications possessed by each for the appreciation of double, simultaneously received, contactile impressions.* But, in addition to the examinations by Weber into the above diagnosing properties of the various parts of the skin, researches also have been made into the subject by others, and among them by G. Valentin,† as noticed in Müller's Physiology, and in the above-cited article on "Touch." Valentin, observing on his own person, as well as on that of others, found that great difference existed among different people as to this contactile recognizing power, and this I have myself also found to be the case in observations practised upon healthy individuals. Indeed I think this might be expected, *à priori*, inasmuch as people are naturally endowed with various degrees of general sensibility as regards the perception of all kinds of impressions or sensations, and no doubt the above form of tactile sensation, as well as others, will, in a normal condition, vary in keenness according to what is called the individual temperament, as well as according to education and training respective of the general and inherent perceptive powers; and to a slight degree also no doubt, even according to age, sex, &c. Moreover, the character as to thickness, consistency, &c., of the cuticular covering, doubtless modifies this power of discrimination; and I may here state that I have lately had the opportunity of testing this capacity in the person of a young lady who, owing to her having been for several years disabled as to her hands and feet by rheumatic gout, had always led an indoor life, not being able even to sew; and I found that at the tips of her fingers which were very delicate, soft, and thinly covered by cuticle, she could distinguish the impression made simultaneously by the two points of my aphetrie compass when they were less distant from each other than the nearest impressions which Weber states capable at this part of being distinguished.

* A useful synoptical diagram or chart, as it were, and one which now I am engaged in constructing, might be made of the surface of the whole integument of the body, in which the districts or regions of various contactile discriminative endowment might be mapped out, so that at a glance, and for practical and clinical purposes as alluded to later on, it might be seen how much in any given case of Anæsthesia or Hyperæsthesia this contactile sensation differs from the average acknowledged condition. I hope also to make out to what extent more impressions than two can, at the same time, be discriminated by various parts of the integument at certain stated distances apart.

† *De Functionibus Nervorum Cerebraliū*, &c., 1839, page 118.

Valentin, as may be seen by his tables in which the discriminating power of no less than 50 parts of the surface of the human body is given, found that the same portion of the skin might in some exceptional but healthy cases be so highly endowed as to this power that impressions only separated by one-half the distance of that observed in other individuals could be distinctly perceived; and from a comparison between the native countries of those on whom the experiments were tried, he conceives it possible that climate and method of clothing may become elements in the modification of this discriminating property.

Carpenter also, in his article on "Touch," before alluded to, where distinguishing between this form of tactile discriminative power and what is called common sensibility, has said much with the intention of showing that they are distinct,* and instances the fact that the skin of the face is infinitely more sensitive to a smart blow of the finger or filip than is that of the ends of the fingers, which greatly exceeds the skin of the face as regards this form of tactile discrimination.† Moreover, Valentin shows that in certain parts, one side of the body is more exquisitely endowed with the discriminating quality than the other, and that the temperature and degree of dryness or moisture of the surface of the skin are also modifying agents.‡ Some

* As regards what is termed general sensibility, no doubt great confusion has hitherto existed in the minds of physiologists, as Landry, in his new and erudite work, "*Traité Complet des Paralysies*," has demonstrated. That author points out that the cutaneous tactile sensations are not to be put in opposition to general sensibility as an abstract property, for although to be separated from the former, the latter is not an essentially different function, as many would have it, but signifies the mode of feeling extended over almost all the tissues of the body, as regards the vague sensation produced by tactile impressions not capable of furnishing a pure idea of the nature or qualities of the substances causing the impressions.

† Carpenter, as I think, may be inferred from the way in which this illustrative example is mentioned by him, had not arrived at the same conclusions regarding the analysis, so to say, of the tactile sense which Landry has developed. The latter author, whilst ignoring the existence of any substantive or special sense of touch (as may be seen in the results of his researches on tactile sensibility in the *Archives Général de Médecin*, 1852) refers all the tactile phenomena to four primitive, special, and distinct sensations, assignable to separate nervous filaments, and possessing individual and appropriate centres in the great nervous masses, viz., those of temperature, pain, contact and muscular action (*i. e.*, the sensation produced in the muscular tissues by and during their contraction). This being the case, we naturally look for their isolation and independence as well in diseased as in healthy conditions; and are not surprised to meet with instances in which one or other of these sensations alone is preëminently exalted, or diminished, or altogether paralysed in any given portion of the cutaneous or mucous surface.

‡ The tongue and fingers which rank so high as regards contactile discriminative power are less impressionable to temperature than the skin of the eyelids or cheeks, and the extremities of the fingers, so facile in contactile discrimination, are but imperfectly sensitive to painful impressions. Many other

experiments made by Rudolph Wagner* upon tactile discrimination in general, show how very exquisitely this power is possessed by the visual organs. He states that two parallel lines can be distinguished by sight if only 0.00014" apart; and also cites the observation of Valentin that such lines may be perceived when distant only 0.00009".

It is impossible here to follow either of these authors more completely where speaking of all the important points connected with contactile discrimination, or the statements of others on the same subject. I will only now briefly allude to three special sources which may be consulted on the subject in question; they are the observations of Dr. Allen Thompson, Dr. Belfield Lefèvre, and Dr. Graves.

In the year 1833, Dr. A. Thompson contributed to the *Edinburgh Medical and Surgical Journal* (see for that year, No. 116) a translation of the account given to him by Weber himself, not then published, of his discoveries concerning the relative power which the skin possesses in various parts, of recognising double impressions made simultaneously upon it within a given limit. In this communication Dr. Thompson combats the supposition maintained by some that this diversity of appreciation was owing to the various parts being more or less habitually seen than others. He shows that this cannot be the cause, inasmuch as some parts which have a comparatively acute discriminative power are quite beyond the range of vision; for example, in the skin over the sacrum and coccyx this discriminative power is more acute than over the pubes. A notable proof of the truth of this objection of Dr. Thompson is the extremely exalted condition of cutaneous sensibility commonly met with in those who have been born blind. Dr. Thompson seems inclined to attribute the diversity in question to some modification of the skin as regards the method of distribution of the nerves, and the quantity of nervous matter existing in divers parts of the skin. The probability of this supposition has however been since quite negatived by the arguments of Dr. Brown-Séquard.

Again Dr. H. Belfield Lefèvre in his "*Recherches sur la*

instances exist in which the capacity of appreciating impressions of pain, and those of heat or contact co-exist at the same parts in more or less reverse proportions. It is then apparent that the aptitude for, or sensibility to, *contact* is one totally and radically distinct from sensibility to the sister impressions producing the sense of pain, or changes of temperature, and that it may be estimated altogether apart; hence the positive necessity in attempting very accurate physiological or pathological investigations, of measuring and limiting the degree of *all* these kinds of sensibility which may or may not be simultaneously affected.

* *Handwörterbuch der Physiologie*, Bd. ii., page 568.

Nature, la Distribution, et l'Organe du Sens Taetile," 1837, an interesting pamphlet in which he seeks to establish the nature of the contactile sense and the relative value of the different parts of the skin as an organ of the sense of contaet, as also the philosophial and functional anatomy of this organ, has several propositions regarding this discriminative power. Among other things worthy of notice in this work he makes use of a very felicitous expression regarding the discriminative power, and one which if adopted would save much periphrasis. Alluding to the variable distanees at which two points touching the skin are pereceived to be clearly distinet, and at which they give rise to but a single impression, he applies the terms "*limit of distinction*" and "*limit of confusion*" respectively. He shows very clearly that the faculty of perceiving delicate differencees of temperature is espeially situated in the integument of the face, and that in this respect the skin of the jaws, eyelids and oleeranon is much more delicate than the skin of the tongue, lips and extremities of the fingers, which latter parts are however the most highly endowed with contactile diseriminative power.

Dr. Graves, of Dublin, also had a paper in the New Philosophical Journal of Edinburgh, in 1836, on the sense of touch, with an analysis of Weber's labours on that subject.

The above brief observations regarding certain faets eonneeted with tactile sensations will suffice, I hope, to show how interesting the subject, as now considered, is in a physiological aspect; and it might readily have been anticipated that their discovery would ere long be utilized and turned to some prae-tical purpose, which has proved to be the case. Those who may advert to the proceedings of the Soci  t   de Biologie at Paris, to our Medico-Chirurgical Review in London, and to the Journal de Physiologie, by Brown-S  quard, will find that the laws concerning contactile discrimination first evolved by Weber,* and in some points more fully brought out and elaborated by later observers, have been applied as methods of deteeting and measuring various degrees of contaetile an  sthesia or hyper  sthesia in diseased eonditions for the purposes of diagnosis or prognosis.

Dr. Brown-S  quard was the first to make this adaptation. In the first volume of the "Comptes rendus des S  ances de la Soci  t   de Biologie," page 162, will be seen a communieation by

* Landry supposes the diversity shown by different parts of the surface of the body in respect of the contaetile sensibility, to be rather a manifestation or expression as it were, of the degree of perfection of the taetile organs than of an inequality in the distribution of the sensibility; being, in faet, an indication of tactile preponderance or intensity, so to say.

him entitled "Recherches sur un moyen de mesurer l'Anæsthésie et l'Hyperæsthésie," wherein he relates the particulars of eleven clinical cases in which by means of a pair of ordinary mathematical two-legged compasses, a deficiency, or an exaltation of contactile discriminative power in the fore-arm and legs was carefully ascertained and measured. In one case, although the two points in contact with the skin were 10, 15 and 20 centimetres apart, yet the sensation perceived was that of a single point only. In one case of paraplegia the two points applied simultaneously to the feet were distinctly appreciated when only separated to the extent of 5 millimetres (the limit of distinction being here from 20 to 25 millimetres). In this case sensibility to pain was also exaggerated. Again at page 280 of the 41st number (January 1858) of the British and Foreign Medico-Chirurgical Review is the description of an ingenious instrument called the "æsthesiometer," and contrived by Dr. Sieveking for measuring the nearest distance at which two points made to impinge upon the skin in certain cases of paralysis, give a two-fold impression. This is accompanied by one or two cases showing the utility of the instrument,* and by a drawing from which it appears that it is not very dissimilar to the instrument the "Stangenzirkel" used in his physiological researches on the tactile sensations by Weber in the first instance, as alluded to above (page 323).

Similar also in principle to this one of Dr. Sieveking's is another instrument for the same purpose used by Dr. Brown-Séquard, and described and figured by that physiologist at page 346 of the first volume of his *Journal de Physiologie*, 1858. This latter instrument differs from that of Dr. Sieveking in having a longer handle, so that, as Brown-Séquard thinks, greater facility for application and for the *simultaneous* contact of the two points, so absolutely necessary, with the cutaneous surface is permitted.

It occurred to me that several advantages would arise if an instrument could be constructed combining the principle of the beam-compass with that of the so-called mathematical one; and accordingly I had one fabricated which has appeared to me to answer the desired purpose.†

* At page 504 of No. 45 of the same journal Dr. Sieveking gives a striking additional case, exemplifying the use of the instrument; showing the difference in the power of the skin, between the discrimination of painful impressions and that of merely contactile ones.

† It was made for me by the well known firm of Messrs. Elliott and Co., instrument makers, Charing Cross, London, whose foreman Mr. Becker, after learning the principle on which I desired the instrument to be constructed, supplied all the calculations, &c., involved in the delicate graduation of the dial-plate, &c.

Description of the Aphemetric Compass.—The instrument, which is about $4\frac{1}{2}$ inches in length, consists of a pair of mathematical compasses with the usual joint, furnished with a circular dial-plate, whose circumference is divided into inches and tenths and twentieths of an inch, and provided with a central hand or indicator (Fig. 46, 1), which may be moved in any direction, so as to point to the various subdivisions. This dial is attached to the anterior surface of one of the legs of the compass, and the indicator on its face is moved by means of a small wheeled pinion behind the dial, of which the pivot is connected with it through the dial. Into this wheeled pinion (*b*) behind the dial works a segment of a tooth-wheel (*c*), which is attached to the other leg of the compass in such a manner that when the legs are separated, that is when the compass is opened, the tooth-wheel working in the pinion moves the indicator on the face of the dial and makes it point to the various subdivisions.

Thus, as these subdivisions are calculated and constructed with reference to the fact that the legs of the compass open round a centre, and not in a straight line, (and consequently are not made equal) the exact distance at which the points of the compass are separated may at once be “read off” on the graduated face of the dial-plate.

In manipulating with this instrument the readiness of measurement, owing to the great length of the graduations on the dial-plate and the quickness with which the corresponding distances* between the separated points of the compass are registered on the dial arc at once apparent.

Moreover, the handling of the instrument, owing to the ease with which the two legs can, with one hand, be drawn

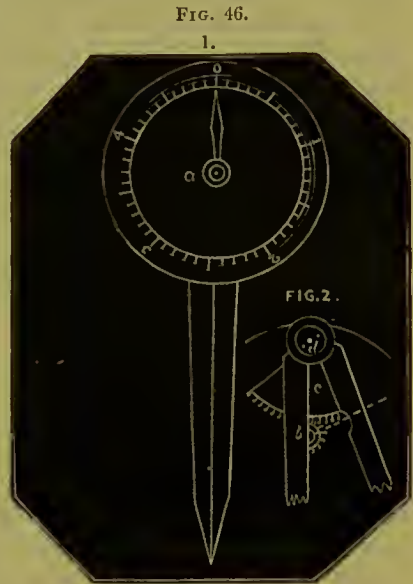


Fig. 46.—1. Shows the front view of the graduated dial-plate, with the indicator.
2. Shows the posterior view, with the tooth-wheel working in the wheeled pinion.

* The intervals on the dial-plate between the degrees or various marking lines of division will of course be found, on observation, to be much larger than the space between the points of the compass when opened and separated to a given amount, which each one expresses.

from each other, whilst at the same time the distances between them are simultaneously and clearly indicated (a process which greatly aids rapid observation) is preëminently convenient. Again, its value is enhanced by the fact that it may be used much more freely than the instruments (formed of a straight piece of metal) already spoken of for measuring contactile discriminative power, in the measurement about the joints, or wrists, or feet, where an irregularity or considerable convexity of the surface obtains. I must allow that, as regards its application, this instrument which I have had made does not quite possess sufficient range of measuring power, as it is not quite able to measure five inches of the surface; but of course this defect is easily remedied in future instruments of the kind.*

In conclusion, I cannot help saying, that although the application of Professor Weber's physiological discovery to clinical and pathological purposes is most admirable and interesting, yet it has not been found by me to be so very extensively practical as might have been supposed. I have made use of it as a means of diagnosis in very many instances, which I need not now detail, and in numerous cases, owing to the peculiar mental condition attendant upon the cause of the sensory paralysis which was under investigation, I have found that the perceptions and the statements of the patient could not be at all considered trustworthy. The complication of intellectual weakness with the pathological interference as regards sensory and motor paralysis, and the natural obtuseness when in health, and want of habit, in attending precisely to any sensations whatever, or in explaining any sensations of which the mind may be cognisant, (met with so often, especially among hospital patients,) have not infrequently rendered this mode of diagnosis and prognosis by means of the aphemetrical compass perfectly nugatory. Add to this

* I have given to this instrument the name aphemetric compass, rather than the neater and more euphonious one of æsthesiometer, inasmuch as I was desirous that its designation should be one carrying its own meaning with it as much as possible. The word æsthesiometer would of course apply to an instrument intended to measure the degree of any kind of sensation whatever, whereas the title "*aphemetric compass*" only has reference to the sense of *contact*, and in a more accurate way than æsthesiometer indicates the use and application of this instrument.

This instrument obtains favour also, I was glad to find, with others than physiologists and physicians. One skilled in mechanics and mathematical appliances spoke in a highly favourable way of its future use for quickly and accurately reducing geometrical distances in the construction of plans, engineering diagrams, &c.; and of its serving, in a superior manner, the purpose of the calipers in ordinary use.

Perhaps, if the limbs of the compass were somewhat arched, this intention of geometrical mensuration would, by making it useful in the case of solid bodies, &c., render it still more generally available.

also the extreme necessity for precautionary measures in the use of the instrument, as before stated, and the obstacles likely to arise from the differences normally found as regards contactile sensibility in different people, which moreover may also exist in the same individuals as regards different parts of their skin, and it will be easy to conceive the existence of cases in which anything like an accurate and reliable measurement of this discriminative power becomes futile.

These qualifying observations I am induced to offer, lest others might be inclined to place too high a value upon a comparatively novel application to clinical medicine of a physiological fact which nevertheless undoubtedly possesses great practical importance.
